MARS SURFACE COMPOSITIONAL UNITS FROM THE MARS EXPRESS HIGH RESOLUTION STEREO CAMERA.

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Introduction: The High Resolution Stereo Camera (HRSC) on the Mars Express (MEx) spacecraft in orbit about Mars is delivering images of the Mars surface and atmosphere from its high-inclination, elliptical orbit that are intended to cover most of the Mars surface by the end of the mission. These include in four specific spectral passbands from near 0.4 µm to about 1 µm. The HRSC focal plane consists of nine linear array Si-CCD detectors, each consisting of 5184 pixels that view the scene, oriented perpendicular to the orbit track. An image is built up by repeatedly reading out each array as the spacecraft orbits over the surface and the scene sweeps across the camera focal plane. Each detector array views the scene at a different angle spread out from forward to aft of nadir so that each detector views a different line in the scene at any instant of time. A pixel is about 10 x 10 m at periapses but the color channels are usually operated in a 2x2 or 4x4 pixel-summing mode. The data are compresses according to the scene brightness activity.

We explored through spectral analysis the surface unit mapping capabilities of the HRSC color data and coupled this with surface feature identification from the high resolution nadir channel and topography from the stereo capability [1]. One result is some important new information about Mars geology.

Reflectance Spectra: Deriving reflectance in each color channel for each pixel involves using the radiometric calibration for the instrument and then removing the effects of the Mars atmosphere and the lighting and observation geometry for each color channel pixel. The atmospheric effects due to the different viewing geometry for each channel are complex so after correcting for sun angle we first assumed that the reflectance of one surface unit is known and adjusted the HRSC spectrum accordingly. We selected the dark deposits, which we assumed to be basalt. This produces reasonable results for all scenes studies so far, both polar and equatorial.

Spectral units: The reflectance values for each color channels for a pixel on Mars define a four-dimensional data space that contains all possible spectra. Each 4-valued location in the 4-space can be thought of as defining a vector from the origin to the location in 4-space. We explored this space without using the "basalt correction" for a number of HRSC scenes and Mars regions. Using the approach of

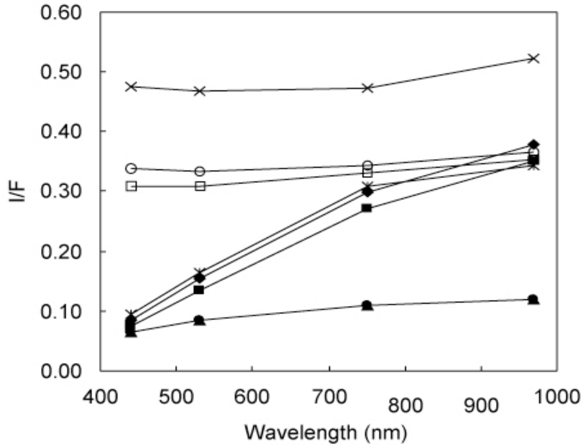

Fig. 1: Reflectance spectra for three major surface units: water ice (bright-flat), red dust (middle-red) and basalt (dark-red).

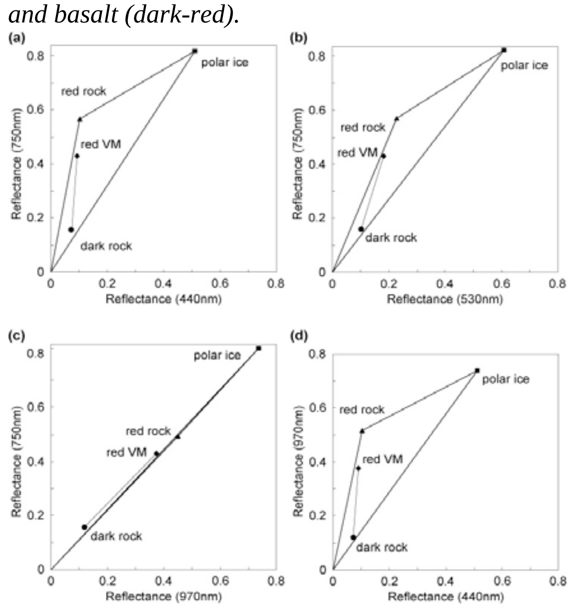

Fig. 2: Vectors of basic spectral components projected onto the planes of the HRSC spectral channel, corrected for solar elevation. Endmembers are dark rock/dunes, red rock, polar ice, and shade/shadow (plots at the origin).

spectral mixing analysis, we find that the three basic spectral types shown in Fig. 1 plus shade/shadow are the basic four types that, with their mixtures, represent most of the Mars surface that we have so far analyzed [Fig. 2]. Other minority materials, such as salts, are implied but not proven by vectors lying off these mixing lines. We used these definitions to map spectral types for geologic interpretation.

Example Geologic Findings: The red and dark spectral types define two main geological units in the Valles Marineris region, in the context of the HRSC images. The red unit dominates the plains that surround the canyons, the upper parts of the canyon walls, and some of the islands within the larger chasmata. Local outcrops of the red unit occur within the dark unit on the valley floors. In HRSC nadir images and MOC images, some of these outcrops exhibit fine layering. The dark unit makes up most of the floors of the larger chasmata, where it occurs as extensive smooth plains, occasional dunes and uncommon layered deposits. It also occurs in conical depressions within the red unit, as talus slopes, and in a wide variety of irregular patches. The dark unit is locally present on the high plains near the rims of the chasmata. Although the red unit is topographically above the dark unit on a regional scale, the contact between the two is nearly everywhere broadly gradational [Fig. 3], and, locally, dark material appears to have intruded and altered the red unit.

Our spectral definitions of the red and dark units have potentially important implications for interpreting the geology of Valles Marineris. The red, high-albedo deposits within the chasmata are spectrally indistinguishable from the materials that comprise canyon walls, rims and the surrounding plains. If these materials all have approximately the same composition, the interior deposits may be part of the Hesperian/Noachian "basement" that comprises the canyon walls and plains, rather than younger deposits that lie unconformably on the basement as previously proposed, e.g., [2]. Many workers have lumped the low-albedo materials in the chasmata together with the high-albedo materials as part of the younger, interior deposits. Our spectral definition of units, however, indicates that the dark-material unit is compositionally distinct from the red, high-albedo material.

Layers of the dark unit are present in the deepest parts of Mellas Chasma and may be stratigraphically below the red unit. We find no evidence that the red unit occurs stratigraphically below the dark unit, as would be implied if the Hesperian/Noachian basement materials had been down-faulted to form the floor on which younger, dark materials were deposited. Excluding dunes and dust deposits, the main interface between the red and the dark units in the chasmata is morphologically complex and extends over an altitude range of several kilometers. Furthermore, the contact is everywhere gradational, e.g. Fig. 3. If the dark material is basaltic in composition, it is difficult to explain the observed complex and gradational zone as a depositional contact between dark flows/tephra and overlying lighter deposits. On the other hand, it does not appear that the dark unit is simply intrusive into the red one, although in places there is evidence that the dark material has followed fracture zones into the high-albedo material and can be seen in the chasmata walls. We are exploring alternative hypotheses for the stratigraphy of Valles Marineris, but, for now, we suggest that understanding the interface between the red and dark units is essential for understanding the origin of the Valles Marineris region.

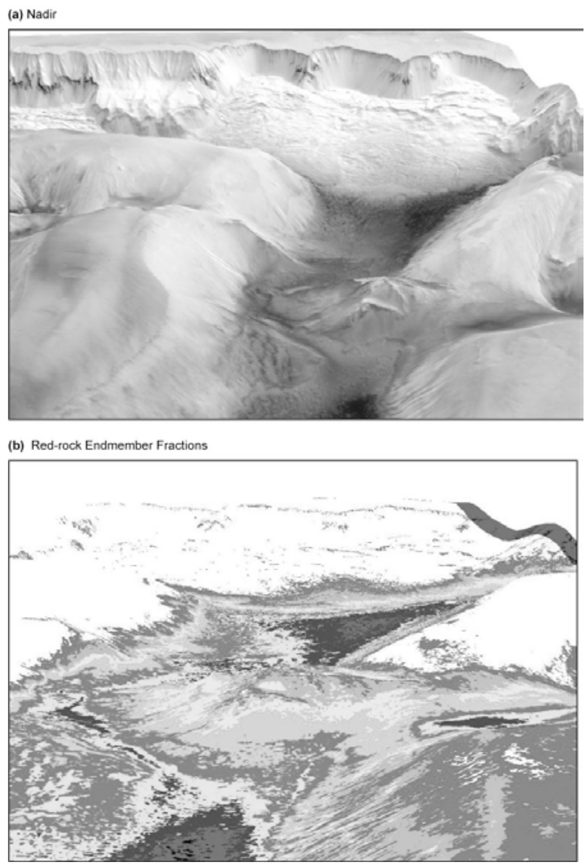

Fig. 3: View is toward the north wall of Ophir Chasma. (a) Nadir image combined with a digital-elevation model. (b) Grayscale-ranked 10% fraction intervals of the red-rock spectral unit combined with a digital-elevation model to show gradational nature of the dark to red rock contact.

References: [1] McCord T. B., et al. (2006) *JGR*, submitted. [2] Witbeck et al., (1991) U.S.G.S, Misc. Investigation Series, Map I-2010.